International Journal of Green Energy

ISSN: 1543-5075 (Print) 1543-5083 (Online) Journal homepage: http://www.tandfonline.com/loi/ljge20

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To cite this article: Michael Rezec & Bert Scholtens (2016): Financing Energy Transformation: The Role of Renewable Energy Equity Indices, International Journal of Green Energy, DOI: 10.1080/15435075.2016.1261704

To link to this article: http://dx.doi.org/10.1080/15435075.2016.1261704

Accepted author version posted online: 28 Nov 2016.

Financing energy transformation: The role of renewable energy equity indices

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Abstract:

The support of financial markets for the transformation of the energy system to a low carbon society seems critical for its success. But will they support this transformation on the basis of market incentives alone? This study analyses how equity indices that try to capture renewable energy investments perform compared to conventional benchmark indices. Especially financial market investors – such as pension funds, insurance companies, and mutual funds – use these to assess and guide their renewable energy investments. As such, we take the perspective of financial market participants, which mainly only indirectly invest in renewable energy. We also analyze whether renewable energy indices are to be regarded as an example of market environmentalism. We find that the renewable energy indices' risk-adjusted return is very poor and suggests renewables is not a financially attractive portfolio investment yet. We also argue that renewable energy equity indices can be regarded as an example of market environmentalism, especially with respect to commodification and frame-shifting.

Keywords: Energy finance; Investments; Stock markets; Renewable energy.

Financing energy transformation: The performance characteristics of renewable energy equity indices

1 Introduction

European governments view renewable energy investments as an essential part of achieving the abatement objective of an 80 percent reduction of greenhouse gas emissions of the 1990 levels by 2050. The share of renewables in European energy consumption has increased from 8% in 2005 to 15% in 2013, and is expected to rise to 20% in 2020, while the European Union (EU) wants to be fully reliant on renewable energy sources by the end of the 21st century (European Environment Agency, 2016). As such, this implies an enormous investment challenge and, amongst others, the accommodating role of financial markets will be critical for the transition towards a society that is fueled by renewable energy sources. Tagliapietra (2013) argues that the private energy sector is set to require Euro (EUR) 1.1 trillion, of which EUR 400 billion for distribution networks and smart grids, EUR 200 billion for transmission networks and storage, and EUR 500 billion for generation capacity. Hence, the support of financial markets could be critical for the success of the energy transformation towards a low-carbon energy system. The private sector is thought to have a comparative advantage in the efficient allocation of scarce funds, although it is notoriously poor at handling externalities to production (Heal, 2008). Gómez-Baggethun and Muradian (2015) offer a recent review of the literature on the impact and meaning of market instruments in dealing with environmental problems. They are especially concerned with the scope for these instruments in arriving at a societal legitimization of dealing with environmental challenges. They also point at the risks of framing of environmental issues and the commodification of resources. A basic distinction we need to make here is that between direct and indirect investing. Direct investors in renewable energy are venture capital investors (Bürer and Wüstenhagen, 2009), citizen investors (Yildiz, 2014), local cooperatives (Van der Schoor and Scholtens, 2015). This particularly relates to decentralized renewable energy projects. However, upscaling these projects faces several challenges, among which financial (Beerman and Tews, 2016; Van der Schoor and Scholtens, 2015). In this respect, institutional investors might play a role (Scholtens, 2006) and they will want to assess the renewable energy investments from a portfolio perspective. However, they mainly invest in tradeable assets and do only to a very limited extent engage with directly financing renewable energy projects as a consequence of their financial imperative in relation to risk management. Thus, to tap into the potential of these financial giants, it is important to securitize energy project debt into investable assets. This allows the institutional investors to benchmark financial performance of their energy investments with renewable energy indices. Such indices are 'baskets' of particular investments in renewable energy projects and companies. Therefore, in this paper, we will investigate the main properties of renewable energy indices from the perspective of indirect investing, i.e. the financial market perspective, not the energy project perspective.

We combine a quantitative analysis with a qualitative assessment regarding the role and reach of renewable energy equity indices. First, we analyze the risk and return characteristics of the international renewable energy equity markets, as this is of interest to financial market participants who contribute in providing the funds to finance the energy transformation. The key questions in this respect are: Does the performance of renewable equity indices differ from that of conventional benchmarks? Do renewable energy equity indices have the same risk as these benchmarks? Can renewable energy indices be replicated on the basis of conventional benchmarks? Will the financial market invest in the transformation to renewable energy on the basis of their own value system? As such, we try to complement the scarce literature that is developing in this area, such as Bohl et al. (2013) who study the volatility of German renewable energy stocks, and Ortas and Moneva (2013) who compare clean tech indices with the market. Our investigation is important to understand whether renewable energy investments may substitute for conventional energy investments by institutional investors in the future and whether this transformation could be purely market driven. The increase in renewable energy in the recent past suggests that the business model of many conventional energy and utilities firms could become obsolete. In addition, fossil energy divestment campaigns threaten part of the asset base of conventional energy producers to turn into "stranded assets" (Scott, 2013). Several foundations in the United States and British endowment funds are vocal supporters of divesting from fossil fuels and of investing more in renewable energy (e.g. Ansar et al, 2013; Vittorio, 2014). Second, we try to connect our analysis of renewable energy equity indices to the critical assessment of the impact of this instrument in the transformation of the energy system on the basis of the framework of Gómez-Baggethun and Muradian (2015). As such, we try to arrive at an overall perspective of renewable energy equity indices. This is motivated by the debate about the public support for renewable energy in several countries, for example in Germany (Hirschhausen, 2014). Gómez-Baggethun and Muradian (2015) point out that so-called market environmentalism has become highly influential. They review the literature and conclude that the market perspective has some important consequences. First is that this perspective conveys the notion that the solution to environmental problems is to be found in the technical domain.

Second, that it reduces the view about potential policy instruments. Third is that the market perspective can erode cultural barriers to the extension of markets and market values to domains that were traditionally governed by non-market norms.

We rely on an international sample of fourteen renewable energy equity indices for the period 2000-2013. In fact, these fourteen constitute the whole domain of these indices at the end of 2013. When analyzing portfolios, it is of interest to assess whether one set of assets can improve the investment opportunity set of another one. We find that the majority of the renewable energy indices do not substantially deviate from their benchmarks. In the period studied, all renewable energy indices studied show quite poor financial performance. As to the qualitative assessment of renewable energy equity indices, we find that they can be regarded as example of market environmentalism indeed. By focusing on financial properties, they are a means to exclude the biophysical, social, and institutional aspects of energy transformation. Furthermore, they may result in frame-shifting regarding the social responsibilities of institutional investors.

The structure of the remainder of our paper is as follows. Section 2 introduces the data and motivates our research design for the quantitative analysis. Section 3 discusses the performance, risk and spanning tests for the individual renewable energy indices. In section 4, we discuss the implications of renewable energy indices in the perspective of the framework of Gómez-Baggethun and Muradian (2015). Section 5 concludes.

2 Data and Method

We collect monthly total return index data either from Thomson Reuters Datastream or, whenever available, directly from the suppliers of the indices. We match each renewable energy index to its official equity benchmark as indicated in its prospectus. However, several indices do either not report official benchmarks, or do not have prospectuses readily available. Then, as the indices have different geographic investment objectives, we use regional and country specific benchmark factors. Institutional background and general information regarding the fourteen renewable energy indices in provided in Appendix A. It shows that most of them have a general benchmark index (such as MSCI Europe, MSCI World, S&P500) and are provided by market specialists. Their constituents differ widely and the investment objective mainly is geographically based. There is a minimum threshold in relation to the income ratio for revenues from renewable energy business. Alternatively, some indices rely on a liquidity ratio and others on trading volume and/or market capitalization to screen for market liquidity of the investment object. The indices clearly differ regarding the range of specific renewable energy technologies included.

We calculate mean excess returns, standard deviations, and risk-adjusted Sharpe ratios. The Sharpe ratio is widely used to compare the risk-adjusted performance of different investments as it relates return to variability and measures the excess return per unit of deviation of an asset, but it is not to be interpreted directly as it is dimensionless (Coates and Page, 2009). Decision making on the basis of the Sharpe ratio only requires detailed information about investor preferences and characteristics about which we lack information. We want to point out that the Sharpe ratio is not stable over time and subject to changes in the underlying fundamentals. We compute the Sharpe ratio using the following equation:

$$SR_i = \frac{r_i^a - r_f}{\sigma_i} \tag{1}$$

where, r_i^a is the annualized mean return for asset i, r_f is the risk-free rate proxied by the transformed (annualized) 3-month US treasury bill, and σ_i represents standard deviations of logarithmic returns. The sample period starts at the beginning of each renewable energy index and ends in February 2013.

Table 1 displays summary statistics for all fourteen renewable energy indices and their benchmarks. The indices are characterized by poor (negative) returns and high volatility. Ten out of the fourteen renewable energy indices have negative annualized mean excess returns. These range between -1 and -16 percent per annum in the period studied (see columns 4 and 5 in Appendix A). Four of the renewable energy indices show positive annualized mean excess returns, ranging between 1 and 3.3 percent annually. The annualized standard deviations of the renewable energy index returns are substantial and range between 17 and 55 percent. Adjusting for risk, we find primarily negative Sharpe ratios for 12 out of 14 renewable energy returns. However, negative Sharpe ratios do not provide useful information because the risk-free asset is then outperforming the investment on a risk-adjusted basis. Such negative Sharpe ratios are quite common during bear markets and hence it is understandable that we find them here (see also Coates and Page, 2009. Two renewable indices, S&P Global Alternative Energy and Nasdaq Renewable Energy, have small positive Sharpe ratios. Furthermore, Table 1 shows that two out of five conventional benchmark indices have negative annualized mean returns in excess of the risk-free rate. Three conventional benchmark indices have positive annualized mean returns in excess of risk-free rate. The total index risk, as proxied by the annualized standard deviation of the conventional indices varies from 17 to 26 percent. The major conventional benchmark indices have Sharpe ratios which are close to zero. Hence, it appears that renewable energy indices, like the conventional counterparts, show rather poor financial performance in the period under review. In general, this would make renewable energy an unattractive industry from the institutional investor perspective. However, one should realize that renewable energy is an 'infant industry' and that investors will analyze prospects and not only base their decisions on recent performance. Further, in the overall market capitalization, the energy industry makes up about ten percent of the total and this usually is reflected in the institutional investment portfolios to keep in line with or track market performance. Therefore, we will dig deeper into the performance of the renewable energy equity indices.

[Insert Table 1 about here]

Regarding the assessment of the performance of the renewable energy indices, we will use the same approach as Schröder (2007) who investigates the performance characteristics of socially responsible investment indices (see also Ziegler and Schröder, 2010). Schröder tests for mean-variance spanning by comparing socially responsible investment (SRI) indices and non-SRI indices. Spanning relates to the issue whether including a new set of assets will improve the minimum-variance frontier from a given set of assets. Hence, it is a means to find out whether a change in the portfolio composition would significantly impact the portfolio performance, or whether one can replicate portfolio performance with a different combination of assets. In contrast to Schröder (2007), we focus on renewable energy indices and compare renewable and non-renewable stock indices. In our view, this is much more focused research as the practical definition of sustainability is problematic as it is not straightforward to distinguish more from less sustainable firms (Chatterji et al., 2009). By exclusively focusing on renewable energy, we think the demarcation is much more clear. Our analysis is related to some other studies. Ortas and Moneva (2013) compare clean tech indices with the market in general. They find that clean tech outperformed the market portfolio during several years. More recently, however, this is no longer the case. Bohl et al. (2013) show that German renewable energy stocks are highly volatile. Cummins et al. (2014) perform a price discovery analysis to discover Granger causation relationships for 'green' equity indices and a set of commodity and broad equity markets. They conclude that green indices increasingly become integrated in mainstream markets. Henriques and Sadorsky (2008) and Kumar et al. (2012) investigate the relationship between oil prices and renewable energy stock prices. The former find that technology stock prices and oil prices each individually Granger cause the stock prices of alternative energy companies (i.e. changes in both technology stock and in oil prices precede alternative energy stock price changes). Kumar et al. (2012) find – on the basis of data from three clean energy indices - that oil prices and technology stock prices separately affect the stock prices of clean energy firms.

By studying an international sample of renewable energy markets, we will also want to investigate geographical aspects of the risk profiles. Geographical investment risks tend to be driven by the resourcefulness of the local natural environment and promotion policies by local governments. The first argument is straightforward as some countries or regions tend to have more favorable conditions with regard to the availability of natural resources. Hence, some forms of renewable energy will realize their full potential better in some regions than in others (Iskin et al., 2012). Another influential reason why investment risks might differ geographically is the different approaches taken by governments to impact renewable energy production through policies, subsidies, taxes and other regulations (Fischer and Newell, 2008). We also observe shifting investor interest towards risk management and risk reduction, especially due to the aftermath of the 2008-2009 economic downturn. This shift towards improved beta management (i.e. constraining a manager to a specific investment style while at the same time managing one's equity allocation) is generally desired by large institutional investors such as pension funds and, more recently, a growing interest in alternative investments such as renewable energy companies (Sadorsky, 2012a).

3 Financial comparison of conventional and renewable energy equity indices

We will investigate the fourteen renewable energy equity indices from all over the world for the period 2000-2013 and for related sub-periods (see Appendix A). We rely on single and multiple equation systems and test for spanning. We will use three different types of benchmarks to measure the relative performance of the renewable energy equity indices. First, there is the domestic country/region benchmark, which is deliberately selected to approximate the investment universe of the energy equity index as close as possible. Second, we perform several additional tests using groups of indices as the benchmark for every renewable energy index. We do so in order to improve the quality of the single-equation tests by using information from the cross-section as well. Third, we perform robustness tests using an established well-diversified index such as MSCI as the benchmark for renewable energy index groups.

3.1 Performance, Risk and Spanning Tests for Individual Renewable Energy Indices

We measure the relative performance of the renewable energy equity indices with the help of a linear regression of the excess returns of a benchmark index on the excess returns of the renewable energy index:

$$r_{i,t}^{REI} = \alpha_i + \beta_i r_{i,t}^{BM} + \varepsilon_{i,t} \qquad (2)$$

where, $r_{i,t}^{REI}$ and $r_{i,t}^{BM}$ are logarithmic excess returns of renewable energy indices, and conventional benchmark indices, respectively. All returns are denominated in US dollars and we compute excess returns using the 3-month US T-bill. α_i refers to Jensen's alpha, a constant, which is a relative performance indicator of over- or underperformance between renewable energy and conventional benchmark returns. β_i represents systematic risk and indicates the riskiness between the two assets. We assume that with beta coefficients where $\beta_i > 1$, the renewable energy index is to be regarded as being riskier compared to the conventional equity benchmark. In contrast, the case of $\beta_i < 1$ indicates lower risk for the renewable energy index. ε_{it} is the error term. Using linear ordinary least squares (OLS) regressions with robust standard errors, we will estimate equation [2] for each of the renewable energy indices in our sample individually.

In terms of a mean-variance spanning test, the renewable assets *span* a larger set of the renewable *and* excluded assets if an investor cannot become better off in mean-variance terms from also investing in the excluded assets (De Roon et al, 2001). In this case, the mean-variance frontiers of the renewable assets and the excluded assets coincide. Testing the joint hypothesis of H_0: α_i =0 and β_i =1 is equal to a spanning test (Huberman and Kandel, 1987). This means that if we do not reject the null hypothesis of spanning (Wald's joint coefficient test), then the renewable energy index can be replicated by the benchmark index. In other words, from an investor perspective, there would be no difference in either investing in renewable energy indices or in the conventional benchmarks, as the return and risk characteristics would be identical. Further, as always, one should, keep in mind that this type of research may generate both type I and type II errors.

In Table 2, we report regression results of our performance tests, i.e. return and risk characteristics of renewable energy indices and their appropriate conventional benchmark indices (this data is not annualized). The adjusted R^2's in column 4 show what is the proportion of the variation in the dependent variable accounted for by the explanatory variables. Column 5 shows our estimated alpha coefficients using OLS regressions. We then perform a Wald test on the null hypothesis, H_0: α_i =0, and find that the Jensen alphas (i.e. the relative risk-adjusted financial performance) are in most of the cases not significantly different from zero. This indicates that the majority of the renewable energy indices do not substantially deviate from their benchmarks. But, as was already clear from Table 1, the risk-adjusted losses are economically substantial. This is because the benchmark excess returns from Table 1 are generally 1% per annum or less and the Sharpe ratios are close to zero (implying an almost flat Capital Market Line and Security

Market Line). Therefore, the higher risk of the renewables does not lead to their expected return being much higher than their benchmark. The estimated beta coefficients and significance levels for testing the null hypothesis H_0: $\beta_i = 1$ are given in column 6. For 12 out of 14 renewable energy indices, we find beta coefficients exceeding one. This indicates significant higher relative risks compared to their conventional benchmarks. Only a minority of renewable energy indices either has non-significant beta coefficients or has beta coefficients below one.

[Insert Table 2 about here]

In the final column of Table 2, we compute a joint coefficient significant test or spanning test with as the null hypothesis: ($\alpha_i = 0$ and $\beta_i = 1$). This shows that spanning is rejected for 13 out of 14 renewable energy indices. As we concluded from our previous individual coefficient tests, the rejection is mainly driven by the difference in beta (risk) compared to the respective conventional benchmark. This suggests that investors who are interested in renewable energy indices do not report substantial differences between the return of their investment compared to conventional energy indices (both are limited). However, they do have to expect more risk compared to investing in the conventional energy benchmarks. The rejection of the spanning hypotheses implies that the renewable energy equity indices cannot be replicated by the conventional benchmarks. This means that investing in renewable energy is different indeed. This contrasts with the findings from Cummins et al. (2014) for a smaller and much more heterogeneous sample. From an investor perspective, there seem to be no statistically significant differences in terms of the financial performance between renewable energy and conventional benchmark indices. However, in terms of risk performance, most renewable energy indices carry significantly more risk.

3.2 Performance, Risk and Spanning Tests for Groups of Renewable Energy Indices

In this section, we conduct virtually the same regression tests as in the previous subsection, but in a second stage use cross-sectional information of our sample of fourteen renewable energy indices by estimating systems of equations. These tests are undertaken to improve the performance of our estimated parameters and may provide additional insights into the return and risk characteristics of renewable energy indices.

$$r_{i,t}^{REI} = \alpha_i + \beta_i r_{i,t}^{BM} + \varepsilon_{i,t}$$

$$\dots\dots\dots\dots \qquad (3)$$

$$r_{n,t}^{REI} = \alpha_n + \beta_n r_{n,t}^{BM} + \varepsilon_{n,t}$$

We first estimate n equations using the seemingly unrelated regression (SUR) estimation procedure. As the benchmarks are not identical across regression equations, we may improve the efficiency of the estimator by using generalized least squares (GLS) in this SUR application by allowing for contemporaneous relations between the different error terms. In Table 3, we report the results of estimating equation [3] for different groups of renewable energy indices. Panel A of Table 3 shows three groups of renewable energy indices grouped according to different sample periods. We define the following three groups as long (12/1999 to 02/2013), medium

(01/2002 to 02/2013), and short (01/2005 to 02/2013) time periods. The motivation for these three periods are the differences in the respective index launch date and their related age. Some indices start earlier (as early as 2000) and others did so later. The intention is to investigate whether the 'age' of an index has an influence on the relationship. In the "short" group we include all indices, in the "medium" group we include indices that start in 2002 and in the "long" group we include indices that start from the beginning.

[Insert Table 3 about here]

The third column presents the results for testing the null hypothesis H_0: all α_i =0, and find that none of the Jensen alphas in either of the three groups are significantly different from zero. In general, these findings confirm our results regarding the single index tests in Table 2. Column 4 shows significance tests for systems of estimated beta coefficients. In line with the single-equation estimations, we find that all renewable energy index groups, combined across different time intervals, are significantly different at the one percent significance level. Finally, the last column presents the spanning tests for the three different time period groups of renewable energy indices. These results show that we can clearly reject the joint hypothesis of H_0: (all α_i =0 *and* all β_i =1). for all three periods. As with the single estimations, the rejection is once again strongly driven by the differences in the beta coefficients. This implies that the renewable energy equity indices cannot be replicated by the conventional benchmarks used. Again, this suggests that renewable energy investing structurally differs from conventional investing.

As our sample of renewable energy indices is very diverse with respect to their investment geographies, we also create three renewable energy index groups according to geography, namely Europe, North America, and Global indices. The performance along this characteristic is reported in Panel B of Table 3. Here, column 3 shows that for groups of European and North American renewable energy indices Jensen alphas are not significantly different from zero. These findings support our previous observations. However, and in contrast, we can reject the null hypothesis for our Global group of renewable energy indices at the 5 percent significance level. These findings suggest that the combination of global renewable energy indices underperforms their respective conventional benchmarks. This finding is not surprising because from our single-equation regressions, we already concluded that three renewable energy indices significantly underperformed their benchmarks (namely AGIXL, RENIXX and HFRXALTE, see Table 1 for the abbreviations) and these indices are all in the same global group. Furthermore, in column 4 of Table 3, we report significance tests for estimated beta coefficients. In line with the single-equation regression results and the different time-interval groups of renewable energy indices, we observe that the betas significantly deviate from one. Finally, we reject all spanning tests for the European, North American and Global groups. The rejection is once again driven by the substantial differences in beta coefficients between indices. Concluding, we arrive at strong support for the fact that renewable energy investing is different from conventional investing from the perspective of institutional investors as its return and risk characteristics cannot be replicated on the basis of conventional benchmarks.

3.3 Performance, Risk and Spanning Tests for Groups of Renewable Energy Indices with Global Benchmarks

To evaluate the robustness of our findings and to shed more light on the return and risk characteristics of renewable energy indices, we perform additional tests. For our first robustness test, we will use the system provided by equation [3] and include additional risk factors, namely size and value. We want to estimate the following system for *n* equations

$$r_{i,t}^{REI} = \alpha_i + \beta_i r_{i,t}^{BM} + \gamma_i r_{i,t}^{SC} + \delta_i r_{i,t}^{GV} + \varepsilon_{i,t}$$

$$\dots\dots\dots\dots \qquad (4)$$

$$r_{n,t}^{REI} = \alpha_n + \beta_n r_{n,t}^{BM} + \gamma_n r_{n,t}^{SC} + \delta_n r_{n,t}^{GV} + \varepsilon_{n,t}$$

There is strong correlation between the returns of MSCI World Equity index and MSCI World Small Cap Index, namely 91.15 percent. In order to avoid spurious regression results due to multicollinearity, we orthogonalize MSCI World Small Cap Index from MSCI World Equity index by estimating the following regression equation: $r_{i,t}^{SC} = v_i + \tau_i r_{i,t}^{BM} + r_{i,t}^{SC}$, where $r_{i,t}^{SC}$ are excess returns of the MSCI World Small Cap Index. We then extract the residual of this equation ($r_{i,t}^{SC}$) and use it instead of the original (highly correlated MSCI World Equity Index) series in equation [4]. We now have a correlation of zero percent between our orthogonalized MSCI World Small Cap series and MSCI World Equity return series. In system (4), $r_{n,t}^{GV}$, represents the growth-value factor. We construct it as the difference between the returns of MSCI World Growth minus MSCI World Value. The growth portfolio includes companies with low book-to-market ratios. In contrast, value portfolios contain companies with high book-to-market ratios. Thus, the system of equations [4] above contains a general market factor (MSCI World equity index), and two so-called "style" control factors that proxy for the size and value premiums in portfolios. Also note that Table 3 uses domestic, individual market benchmarks, while Table 4 uses one global market benchmark, namely the MSCI World Index. Thus, the small difference in estimated coefficients between Table 3 and Table 4 can be attributed to the different benchmarks we use. Columns 3-5 give the results from the single factor equations in relation to the MSCI World index. This is the basis of our comparison for the estimation results from system [4]. Again, the results between Table 3 and 4 differ slightly because of the different benchmark choice.

[Insert Table 4 about here]

Column 6 of Table 4 reports Wald coefficient tests on Jensen alphas. In line with our previous findings, we cannot reject the null hypothesis that the alphas are significantly different for any of the three different time interval groups. Hence the ‘age’ of the indices does not seem to matter. In column 7, we test whether the beta coefficients are significantly different from one across groups. Beta coefficients in Table 4 are significantly different from one, as was the case with the beta coefficients in Table 3. Here, we reject the null hypothesis that the beta is equal to one for the three time-interval groups. These findings indicate that systematic risk, as measured by the beta coefficient, differs for renewable energy equity indices compared to conventional market equity indices. Our findings are in line with previous tests based on individual local conventional equity benchmarks from Table 3. Finally, as shown in column 8, the spanning tests are rejected for all three time-interval groups. Once again, we find that there is a substantial difference in the characteristics of the renewable energy equity indices and their conventional equity benchmarks.

Panel B of Table 4 displays the estimations of the regressions provided in system 4 above, but now groups renewable energy indices according to investment geography. Columns 3-5 give the results from the single factor equations on the basis of the MSCI World index. In column 6 of Table 4, it appears that the global group of renewable energy indices has a significantly different Jensen alpha compared to their respective conventional benchmarks. The alpha coefficients of European and North American renewable energy groups are not statistically different. Column 7 shows the regression estimates for the beta, which are highly significant at the one percent level. The last column reports Wald joint significance tests for alpha and beta coefficients combined. As in previous estimations, we find highly significant rejections, that are mainly attributable to the difference in beta coefficients between renewable energy and conventional equity benchmark indices.

The robustness tests confirm the previous results using single equations or equation systems. In particular, renewable energy equity indices, except for a group of global indices, do not exhibit differences in their risk-adjusted return (Jensen's alpha) relative to conventional equity benchmarks. Nevertheless, differences in the return and risk characteristics exist. These differences are particularly driven by the substantially higher relative risk of the renewable energy indices.

The results do not seem to offer a lot of support for the case of investing in renewable energy as financial performance is very poor. However, energy investments to some extent might resemble tech funds (Ortas and Moneva, 2013). In part, the performance of renewable energy stocks reflects the coming of age of an industry. Especially in the early years, it takes time for new ventures to develop and 'mortality' is high. Not only is there a consolidation of renewable energy firms taking place, but due to the increased competition from emerging economies such as Chinese manufacturers, for example in the photovoltaic industry, the prices for solar panels dropped enormously in the recent past. This translates into high risks, which might be exacerbated by the existence of regulatory risk (Fischer and Newel, 2008; Wüstenhagen and Menichetti, 2012). Investors will need to spend additional effort into monitoring their investments in order to try to pick the 'winners'. In addition, Masini and Menichetti (2012) suggest that especially institutional investors are biased towards more established and 'proven' technologies. In our view, the development of secondary renewable energy markets, of which the gradual increase in renewable energy equity indices is a clear witness, is *a conditio sine qua non* for increasing the potential for renewable energy finance. Institutional investors manage enormous sums of money and are able to make do with investment characteristics from which venture capitalist, private investors and banks shy away.

Apart from the perspective of renewable energy which requires huge investments (the so-called 'pull' factor), there also is the other side of the coin (the 'push' factor). This is that institutional investors increasingly are under pressure from different stakeholders to realize that their fiduciary duty is not only limited to making as much money as possible but that they need to account for externalities too. As one pension manager put it to us "*what is the use of sitting on a pile of money in an uninhabitable world*?". This motivates our analysis in the next section.

4 Renewable energy indices and market environmentalism

So far, we especially focused on the financial properties of the renewable energy equity indices. To a great extent, this in fact results from the risk and return lens that comes along with focusing on the financial performance of renewable energy equity indices. However, the impact of investing on for example amount of tonnes carbondioxide emitted, kilowatts of electricity produced, or community empowerment are ignored. This exactly is the effect that results from market environmentalism as described by Gómez-Baggethun and Muridian (2015). Therefore, in this section, we want to change the perspective by assessing in how far this type of indicators can be regarded as an example of market environmentalism. We feel this is warranted as there is increasing public support and funding for renewable energy, which has resulted in a debate about the role of society in the transformation of the energy system (Hirschhausen, 2014). It should be realized that very diverse stakeholders are involved, such as venture capital investors, citizen groups, local cooperatives, local and regional authorities, as well as banks and indirect investors (Bürer and Wüstenhagen, 2009; Yildiz, 2014; Van der Schoor and Scholtens, 2015; Beerman and Tews, 2016). The focus in our paper is just on the financial market participants (investors) who only indirectly participate in this by investing in stock of renewable energy companies.

We use the insights by Gómez-Baggethun and Muridian (2015) to assess the role of renewable energy indices. They review the literature regarding market environmentalism and arrive at three main insights. First is the analytical lens in the way environmental challenges are framed and solutions are proposed. Second is the complexity of the role of market-based instruments. Third is the role of these instruments in the governance of environmental challenges. Regarding the renewable energy indices, due to technological innovation, a new niche market of firms has emerged that contribute to renewable energy solutions. By bundling these firms in renewable energy indices, three results are achieved (see Fortune, 1998). First is that there is a clear demarcation between renewable and non-renewable energy firms. However, we want to point out that lately established energy producers have started to change their strategy and invest in renewable energy generation. As such, they also may come to play a role in the transition towards renewable energy. Another issue is that especially decentralized renewable energy generation is finding it hard to tap into conventional financial markets as of yet. Second is that there is a role for the indices as a performance yardstick for investors. Third is that there has been created a new financial instrument, as one can construct financial commodities on the basis of such indices.

The renewable energy equity indices play an important role in framing. Ultimate investors in pension funds as well as non-governmental organizations (NGOs) put pressure on institutional investors to take a societal responsibility. Lately, this especially is the case with energy investments (see Ansar et al, 2013; Vittorio, 2014). By relating to or investing in renewable energy indices, the institutional investors can relatively easily signal that they account for societal demands. Then, investing in renewables becomes business as usual and the investors will have integrated the grand challenge of society's transformation into their risk and return framework. Renewable energy innovations as such are being translated into financial properties of assets that can be investigated on the basis of the conventional finance framework (see section 3). The renewable energy indices provide a finance and investment frame regarding the energy system that is blind to other dimensions (ethical, biophysical, institutional). Whether the investments actually reduce greenhouse gas emissions or increase the renewable energy capacity, empower communities, etc. is not an issue from the investment perspective. Even investors that have policies on social responsibility usually do not set objectives regarding the materiality. Most items usually refer to rather general policies and internal practices (see Chatterji et al., 2009).

Renewable energy indices only to a very limited extent can be used as instruments themselves in the energy system transformation. This is because they rely on companies that already are listed at an exchange. The indices themselves play no direct role in the take-off of companies that somehow engage with solutions targeted at making the energy system more sustainable. This is rooted in the nature of the markets, namely being secondary financial asset markets (Scholtens, 2006). These markets are about the exchange of existing assets: The buy of an assets by one investor is the sale of this asset by another investor. In this secondary market, the number of assets does not change. Thus, the available funds to directly finance business ventures does not change due to the existence of such secondary markets. Only very indirectly the indices can be used as an instrument that helps solve environmental problems. If more and more investors would want to include renewable energy into their investment portfolio and this would translate into more favorable financial characteristics, it could become less costly for renewable energy firms to attract funding for their investments. In turn, this could increase research and development effort and expenditure in renewables and the capacity of renewable energy generation.

The third insight from the Gómez-Baggethun and Muridian (2015) review is that the market-reasoning can erode the barriers to the extension of market values to domains that are traditionally governed by non-market norms. In this respect, the renewable indices impact on the ways in which investors interact with their owners and other stakeholders. Increasingly, institutional investors are challenged to account for non-financial performance. As a result, responsible investing has become serious business. For example, many institutional investors are signatories to the United Nations' "Principles for Responsible Investment" which advocates the transparency about investments and to include environmental, social and governance issues in their investment policy. As of April 2016, it has 1,500 signatories who have US $ 62 trillion in assets under management (www.unpri.org). Nevertheless, the existence of the renewable energy indices and their use by institutional investors is a step in the commodification of renewables. This is because it shifts the perspective of investors from real renewable energy activity that is taking place at the local and community level to the much more marketable renewable energy activity which occurs at the more traditional commercial level. For example, in Germany, about half of the renewable energy is sourced by entities that have no direct or indirect access to the equity market (Klaus Novy Institute, 2011). In recent years, more and more consumers produce at least part of their own energy. Here, the affix 'prosumers' can be applied to this development of decentralized energy production. Local community energy initiatives foster and stimulate this development, but many go a step further by founding local energy cooperatives (Hoffman and

High-Pippert, 2010). As such, it is important to realize that the indices rely on screens (see columns 7-10 in Appendix A). For example regarding the minimum turnover in the stocks that are allowed in the index or their minimum market capitalization (Flannery, 1998). With our indices, the former is at least $ 1 million, whereas market capitalization is at least $ 100 million. If a firm does not qualify on the basis of these criteria, it will not be included in the index. Then, its investment potential is limited. One should realize that these sizes are way beyond the scope of small enterprises and most local and community initiatives. As such, institutional investors should work on alternatives in order to allow their funds to work for the transformation of the energy system.

To conclude, on the basis of the insights from Gómez-Baggethun and Muridian (2015), we find that renewable energy indices are an example of market environmentalism. This especially relates to the finance and investment lens they suggest regarding the assessment of the transformation of the current energy system towards a more sustainable one. It also relates to the frame-shifting effect it might have regarding the responsibilities of the institutional investors. We do not find that the renewable energy indices act as an economic instrument to advance the transformation of the energy system.

5 Conclusion

Investments in renewable energy are increasing in line with the use of renewables in overall energy generation. Given the enormous challenges of climate change and environmental pollution from fossil sources, it is highly necessary that the investments will increase dramatically in the next decades. To this extent, it is important that there are well functioning financial markets in renewable energy assets. We investigate the performance of renewable energy equity indices and look into return, risk and spanning (i.e. replication). As such, we take a financial market perspective and focus on institutional investors who manage huge amounts of assets. We use a sample of fourteen indices from all over the world for the period 2000-2013, which is in fact the complete universe of renewable energy indices for this period. We ask several questions. First, does the performance of renewable equity indices differ from that of their conventional benchmarks? We show that most renewable energy indices underperform, but also that some of them outperform their benchmarks. However, overall performance is rather poor and they make unattractive investments from a financial perspective. We also investigate whether renewable energy equity indices have the same risk as their benchmarks. Here, we establish that risk with renewable energy indices is significantly higher than that of the benchmark. The third question we investigate is if renewable energy indices can be replicated on the basis of conventional benchmarks. We show that this is not the case, hence investing in renewable energy indices is different indeed. Lastly, we investigate whether the financial market participants would invest in renewables on the basis of their own metrics. Here, we show that because of the poor performance in terms of financial returns and risks, this is not very likely.

So far, most studies regarding financing renewable energy primarily focus on the business case of renewables and on vehicles for direct investing. However, as such, the amounts of funds available for renewable energy are likely to be limited as investors face no exit option. In case there would evolve a market in tradable assets related to these investments, direct investing in renewable energy would become much more attractive. This especially is the case for institutional investors. For these investors, the cost of direct investing in renewable energy is relatively large and liquidity is very limited which makes it an unattractive investment opportunity. They might be much more interested in the opportunity to invest in tradable assets that relate to renewable energy. Institutional investors can provide capital for the deployment of renewable energy to make up for a shortage of potential investment from alternative sources. Furthermore, they are able to mitigate the financing costs on the basis of providing capital with terms, conditions, maturities and risk – return expectations that can differ from those of other market participants. Currently, the finance professionals hardly engage with citizens and local groups who set up renewable energy projects. At the same time, and despite the huge need for funding the transformation towards a more sustainable energy system, there is a 'dark side' of simply relying on financial market institutions. We argue that specifically the finance and investment lens and the frame-shifting regarding the responsibilities of investors might result in more and more financial-technical approach regarding the transformation of the energy system. From a policy perspective, this suggests that policies to enhance the financing of renewable energy should not only focus on reducing the levelized cost of energy and lower the cost of capital for these projects, but explicitly account for social, biophysical, ethical and institutional perspectives. It is important for policy makers to realize that there can be tradeoffs between other policy objectives and the benefits of institutional investment. So far, there are no specific policy elements that aim at encouraging institutional investors to invest in renewable energy. We think it is important to account for different dimensions at the same time without ignoring the potential for negative trade-offs.

Acknowledgements

We want to thank Dr. Li, editor-in-chief of the International Journal of Green Energy, and two anonymous referees for their helpful suggestions and comments on previous versions of the manuscript. Further, we thank Dimitris Chronopoulos, Andreas Hoepner, David Power, Manouche Tavakoli, and John Wilson for their support and encouragement. The usual disclaimer applies.

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Table 1 Renewable energy equity index performance vs. benchmark performance: Overview

Abbreviations (1)	Renewable Energy Index (2)		Benchmark (3)	Mean RE (4)	Std. dev. RE (5)	Mean Conv (6)	Std. dev. Conv (7)	Sharpe Ratio RE (8)	Sharpe Ratio Conv (9)
AGIGL	Ardour Global Alt. Energy		MSCI World	-0.052	0.001	0.380	0.169	-0.055	0.002
AGIXL	Ardour Global Alt. Energy Extra Liquid		MSCI World	-0.079	0.001	0.387	0.169	-0.074	0.002
AGINA	Ardour Global Alt. Energy North America		NASDAQ Composite	-0.074	-0.040	0.398	0.256	-0.069	-0.072
AGIEM	Ardour Global Alt. Energy Europe		DJ Eurostoxx	-0.095	0.010	0.406	0.245	-0.079	0.011
SOLRX	Ardour Global Alt.		MSCI World	-	0.00	0.5	0.16	-0.067	0.002

	Energy Solar			0.109	1	46	9		
DAXAE	Daxglobal Alternative Energy		MSCI World	0.011	0.001	0.284	0.169	-0.006	0.002
RENIXX	World Renewable Energy (Renixx)		MSCI World	-0.157	0.001	0.394	0.169	-0.127	0.002
SPGTAE	S&P Global Alternative Energy		S&P Global 1200	0.020	0.006	0.275	0.173	0.003	0.010
SPATAEUP	S&P Asia Alternative Energy		S&P Asia Pacific	-0.130	-0.023	0.357	0.204	-0.107	-0.030
HFRXALTE	HFRX Alternative Energy		MSCI World	-0.071	0.001	0.362	0.169	-0.071	0.010
CELS	NASDAQ Renewable Edge US Liquid		MSCI World	0.033	0.001	0.177	0.169	0.029	0.001
SPGTC	S&P Global Clean		S&P Global	-	0.00	0.3	0.17	-0.080	0.010

LEN	Energy		1200	0.088	6	57	3		
ERIX	European Renewable Energy		DJ Eurostoxx	0.011	0.01 0	0.4 11	0.24 5	-0.006	0.011
NEX	Wilderhill New Energy Global Innovation		MSCI World	- 0.009	0.00 1	0.2 98	0.16 9	-0.026	0.002

Notes:

This table reports summary statistics for our sample of fourteen renewable energy and conventional benchmark indices respectively. We compute summary statistics from the inception date of each renewable energy index until February 2013. Columns 4 and 5 present annualised mean and annualised standard deviation calculations for each renewable energy index. In the next two columns, we calculate annualised means and standard deviations for the corresponding conventional equity benchmarks. The final two columns report Sharpe ratios of renewable energy and conventional indices. The Sharpe ratio is the ratio of mean excess returns (over risk-free asset) divided by the standard. We annualise monthly standard deviations by multiplying with the square root of 12.

Table 2 Renewable energy equity index performance vs. benchmark performance: Regression Tests

Abbreviations	Start Date	End Date	Adj. R^2	Alpha H_0: α_i=0		Beta H_0: β_i=1		Wald Joint Significance Test H_0: α_i=0 *and* β_i=1	
AGIGL	31/12/1999	28/02/2013	0.608	-0.006		1.753	***	24.986	***
AGIXL	31/01/2000	28/02/2013	0.642	-0.009	*	1.841	***	47.293	***
AGINA	31/12/1999	28/02/2013	0.699	-0.004		1.298	***	16.444	***
AGIEM	30/06/2005	28/02/2013	0.700	-0.011		1.318	***	9.366	***
SOLRX	31/12/2004	28/02/2013	0.528	-0.016		2.274	***	53.474	***

DAXAE	29/12/2000	28/02/2013	0.621	- 0.002		1.313	***	18.702	***
RENIXX	31/01/2002	28/02/2013	0.455	- 0.020	*	1.579	***	22.778	***
SPGTAE	28/11/2003	28/02/2013	0.756	- 0.006		1.405	***	17.312	***
SPATAEUP	30/06/2008	28/02/2013	0.396	- 0.011		1.045		1.965	
HFRXALTE	31/01/2006	28/02/2013	0.695	- 0.015	**	1.797	***	32.926	***
CELS	30/11/2006	28/02/2013	0.611	0.000		0.751	**	11.187	***
SPGTCLEN	28/11/2003	28/02/2013	0.739	- 0.010		1.551	***	23.048	***
ERIX	30/09/2003	31/01/2012	0.646	- 0.005		1.353	***	7.978	**

NEX	29/12/2000	28/02/2013	0.763	-0.004		1.525	***	23.569	***

Notes:

This table contains OLS regression results of fourteen renewable energy excess returns on their respective conventional index excess returns starting from the inception date to February 2013. For abbreviations used, please see to Table 1. We estimate the equation (2) over the indicated sample period. We use Newey/West (1987) autocorrelation and heteroskedasticity robust standard errors. Column 4 reports adjusted R^2 values. The next column reports alpha coefficients and significance levels of testing whether each coefficient is significantly different from zero. Column 6 shows estimated beta coefficients and Wald coefficient tests, whether beta is significantly different from one). The final column reports Chi-square values of Wald's joint coefficient significance test, which is similar to a Spanning test. All returns are denominated in US dollars. *, **, *** indicate significance levels of 10, 5 and 1 percent, respectively.

Table 3 Joint Coefficient-Tests for sample period and geography systems with individual (local) benchmarks

Period	Included Indices	χ^2 H$_0$: all α_i=0		χ^2 H$_0$: β_i=1		Wald Joint Significance Test H$_0$: all α_i=0 *and* all β_i=1	
Panel A: Sample Period							
12/1999 to 02/2013	AGIGL, AGIXL, AGINA, DAXAE, NEX	1.33		39.48	***	40.60	***
01/2002 to 02/2013	AGIGL, AGIXL, AGINA, DAXAE, RENIXX, SPGTAE, SPGTCLEN, ERIX, NEX	13.31		64.68	***	77.10	***
01/2005 to 02/2013	AGIGL, AGIXL, AGINA, AGIEM, SOLRX, DAXAE, RENIXX, SPGTAE, SPATAEUP, HFRXALTE, CELS, SPGTCLEN, ERIX, NEX	19.80		120.07	***	136.44	***

Panel B: Geography+							
Europe	AGIEM, ERIX	3.13		13.49	***	15.65	***
North America	AGINA, CELS, NEX	0.93		82.69	***	83.48	***
World	AGIGL, AGIXL, SOLRX, DAXAE, RENIXX, SPGTAE, HFRXALTE, SPGTCLEN	17.90	**	81.16	***	94.98	***

Notes:

Panel A presents coefficient estimates, Chi-square values and significances for estimating systems of three groups of renewable energy indices formed according to different time intervals. For abbreviations used, please see to Table 1. We divide time intervals in long, medium, and short-term groups. In Panel B, we report the same information for three regional groups of renewable energy indices, Europe, North America, and Global. Estimations are based on system (3) of *n* equation. Column 3 reports alpha coefficients and significance levels of testing whether coefficients are significantly different from zero. The next column shows estimated beta coefficients and Wald coefficient tests, whether beta is significantly different from one. The final column reports Chi-square values of Wald's joint coefficient significance test, which is similar to a Spanning test. ***, **, and * indicate significance levels of 1, 5 and 10 percent, respectively. We do not create a group for Asia because we only have one renewable energy index from that region.

Table 4 Joint Coefficient-Tests for sample period and geography systems with MSCI World & Controls

		Single Factor equation with MSCI World						*Multi-Factor equation with MSCI World plus Small Cap & Growth-Value*					
Period	Included Indices	χ^2 HH_0: all $\alpha_i=0$		χ^2 H_0: $\beta_i=1$		Wald Joint Significance Test H_0: all $\alpha_i=0$ *and* all $\beta_i=1$		χ^2 H_0: all $\alpha_i=0$		χ^2 H_0: $\beta_i=1$		Wald Joint Significance Test H_0: all $\alpha_i=0$ *and* all $\beta_i=1$	
Panel A: Sample Period													
12/1999 to 02/2013	AGIGL, AGIXL, AGINA, DAXAE, NEX	1.76		49.25	***	50.57	***	1.49		65.69	***	66.95	***
01/2002 to 02/2013	AGIGL, AGIXL, AGINA,	14.53		86.81	***	100.16	***	12.60		111.11	***	122.51	***

	DAXAE, RENIXX, SPGTAE, SPGTCLEN, ERIX, NEX												
01/2005 to 02/2013	AGIGL, AGIXL, AGINA, AGIEM, SOLRX, DAXAE, RENIXX, SPGTAE, SPATAEUP, HFRXALTE, CELS, SPGTCLEN, ERIX, NEX	21.48	*	147.82	***	164.38	***	18.59		160.01	***	173.96	***
<u>Panel B: Geography</u>+													

Europe	AGIEM, ERIX	4.65	*	44.41	***	46.31	***	2.71		38.11	***	38.64	***
North America	AGINA, CELS, NEX	2.11		93.16	***	94.91	***	1.37		106.44	***	107.05	***
World	AGIGL, AGIXL, SOLRX, DAXAE, RENIXX, SPGTAE, HFRXALTE, SPGTCLEN	18.36	**	84.68	***	98.77	***	16.64	**	104.47	***	116.55	***

Notes:

Panel A presents coefficient estimates, Chi-square values and significances for estimating systems of three groups of renewable energy indices formed according to different time intervals. For abbreviations used, please see to Table 1. We divide time intervals in long, medium, and short-term groups. In Panel B, we report the same information for three regional groups of renewable energy indices, Europe, North America, and Global. Estimations are based on the following system (4) of *n* equations. Column 3 reports alpha coefficients and significance levels of testing whether coefficients are significantly different from zero. The next column shows estimated beta coefficients and Wald coefficient tests, whether beta is significantly different from one). The final column reports Chi-square values of Wald's joint coefficient significance test, which is similar to a Spanning test. ***, **, and * indicate significance levels of 1, 5 and 10 percent, respectively. We do not create a group for Asia because we only have one renewable energy index from that region.

Appendix A: Renewable energy equity index characteristics

						Clean income screen	Liquidity Screen		
Abbreviation (1)	Renewable Energy Index (2)	Region (3)	Benchmark (4)	Start Date (5)	End Date (6)	Income ratio (ann.) (7)	liquidity ratio* (8)	Trading volume (minimum) (9)	Market capitalization (minimum) (10)
AGIGL	Ardour Global Alt. Energy	World	MSCI World	31/12/1999	28/02/2013	> 50% gross revenues	>25%		
AGIXL	Ardour Global Alt. Energy Extra Liquid	World	MSCI World	31/01/2000	28/02/2013	> 50% gross revenues	>25%		

AGINA	Ardour Global Alt. Energy North America	North America	NASDAQ Comp.	31/12/1999	28/02/2013	> 50% gross revenues	>25%		
AGIEM	Ardour Global Alt. Energy Europe	Europe	DJ Eurostoxx	30/06/2005	28/02/2013	> 50% gross revenues	>25%		
SOLRX	Ardour Global Alt. Energy Solar	World	MSCI World+	31/12/2004	28/02/2013	> 50% gross revenues		$ 1 million	
DAXAE	Daxglobal Alternative Energy	World	MSCI World+	29/12/2000	28/02/2013	> 50% gross revenues		$ 1.2 million	$ 150 million

RENIXX	World Renewable Energy	World	MSCI World	31/01/2002	28/02/2013	> 50% gross revenues				Highest free-float market cap.
SPGTAE	S&P Global Alternative Energy	World	S&P Global 1200	28/11/2003	28/02/2013	> 50% gross revenues or net income			$ 3 million	$ 300 million
SPATAEUP	S&P Asia Alternative Energy	Asia	S&P Asia Pacific	30/06/2008	28/02/2013	Not available			$ 2 million**	$ 250 million
HFRXALTE	HFRX Alternative Energy	World	MSCI World	31/01/2006	28/02/2013	Not available			Not available	Not available

CELS	NASDAQ Renewable Edge US Liquid	US	MSCI World	30/11/2006	28/02/2013	> 50% gross revenues		100,000 shares	$ 150 million
SPGTCLEN	S&P Global Clean Energy	World	S&P Global 1200	28/11/2003	28/02/2013	> 50% gross rev. or net income		$ 3 million	$ 300 million
ERIX	European Renewable Energy	Europe	DJ Eurostoxx	30/09/2003	31/01/2012	> 50% gross rev. or net income		10 largest in sector	10 largest in sector
NEX	Wilderhill New Energy Global Innovation	US	MSCI World	29/12/2000	28/02/2013	> 10% - 50% market value		$ 1 million	$ 100 million

	* liquidity ratio defined as the average three-month daily trading volume divided by the average three-month market capitalization. ** three-month average market capitalization